VOLUME I

SEASAT ECONOMIC ASSESSMENT

SUMMARY AND CONCLUSIONS

ECON INCORPORATED

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FINAL

VOLUME I

SEASAT ECONOMIC ASSESSMENT

SUMMARY AND CONCLUSIONS

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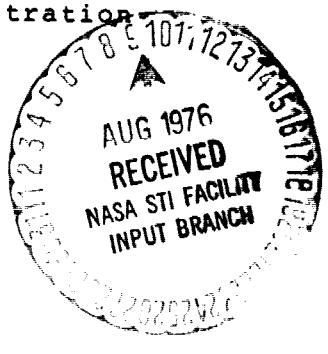

Table 1.1: Content and Organization of the Final Report

Volume No.	Title	Content
I	Summary and Conclusions	A summary of benefits and costs, and a statement of the major findings of the assessment.
II	The SEASAT System Description and Performance	A discussion of user requirements, and the system concepts to satisfy these requirements are presented along with a preliminary analysis of the costs of those systems. A description of the plan for the SEASAT data utility studies and a discussion of the preliminary results of the simulation experiments conducted with the objective of quantifying the effects of SEASAT data on numerical forecasting.
III	Offshore Oil and Natural Gas Industry-Case Study and Generalization	The results of case studies which investigate the effects of forecast accuracy on offshore operations in the North Sea, the Celtic Sea, and the Gulf of Mexico are reported. A methodology for generalizing the results to other geographic regions of offshore oil and natural gas exploration and development is described along with an estimate of the worldwide benefits.
IV	Ocean Mining - Case Study and Generalization	The results of a study of the weather sensitive features of the near shore and deep water ocean mining industries are described. Problems with the evaluation of economic benefits for the deep water ocean mining industry are attributed to the relative immaturity and highly proprietary nature of the industry.

Note of Transmittal

The SEASAT Economic Assessment was performed for the Special Programs Division, Office of Applications, National Aeronautics and Space Administration, under contract NASW-2558. The work described in this report began in February 1974 and was completed in August 1975.

The economic studies were performed by a team consisting of Battelle Memorial Institute; the Canada Centre for Remote Sensing; ECON, Inc.; the Jet Propulsion Laboratory; and Ocean Data Systems, Inc. ECON, Inc. was responsible for the planning and management of the economic studies and for the development of the models used in the generalization of the results.

The studies of the utility of SEASAT data were performed by a team consisting of the Goddard Institute of Space Studies and the Jet Propulsion Laboratory.

The preliminary trade-off studies of possible operational SEASAT systems configurations and costs were performed by the Jet Propulsion Laboratory with the support of ECON, Inc.

The SEASAT Users Working Group (now Ocean Dynamics Subcommittee) chaired by Dr. John Apel of the National Oceanographic and Atmospheric Administration, served as a valuable source of information and as a forum for the review of these studies. Mr. S. W. McCandless, the SEASAT Program Manager, coordinated the activities of the many organizations that participated in these studies into the effective team that obtained the results described in this report.

B.P. Miller

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1. INTRODUCTION

This report, consisting of ten volumes, represents the results of the SEASAT Economic Assessment, as completed through August 31, 1975. The individual volumes in this report are:

Volume	I	- Summary and Conclusions
Volume	II	- The SEASAT System Description and Performance
Volume	III	- Offshore Oil and Natural Gas Industry - Case Study and Generalization
Volume	IV	- Ocean Mining - Case Study and Generalization
Volume	V	- Coastal Zones - Case Study and Generalization
Volume	VI	- Arctic Operations - Case Study and Generalization
Volume	VII	- Marine Transportation - Case Study and Generalization
Volume	VIII	- Ocean Fishing - Case Study and Generalization
Volume	IX	- Ports and Harbors - Case Study and Generalization
Volume	X	- A Program for the Evaluation of Operational SEASAT System Costs.

Each volume is self-contained and fully documents the results in the study area corresponding to the title. Table 1.1 describes the content of each volume to aid readers in the selection of material that is of specific interest.

The SEASAT Economic Assessment began during Fiscal Year 1975. The objectives of the preliminary economic assessment conducted during Fiscal Year 1975 were to identify the uses and users of the data that could be produced by an operational SEASAT system and to provide preliminary estimates of the benefits produced by the applications of this data.* The preliminary economic assessment identified large potential benefits from the

*ECON, Inc., SEASAT Economic Assessment, October 1974.

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Table 1.1: Content and Organization of the Final Report
(continued)

Volume No.	Title	Content
V	Coastal Zones - Case Study and Generalization	The study and generalization deal with the economic losses sustained in the U.S. coastal zones for the purpose of quantitatively establishing economic benefits as a consequence of improving the predictive quality of destructive phenomena in U.S. coastal zones. Improved prediction of hurricane landfall and improved experimental knowledge of hurricane seeding are discussed.
VI	Arctic Operations - Case Study and Generalization	The hypothetical development and transportation of Arctic oil and other resources by ice breaking super tanker to the continental East Coast are discussed. SEASAT data will contribute to a more effective transportation operation through the Arctic ice by reducing transportation costs as a consequence of reduced transit time per voyage.
VII	Marine Transportation-Case Study and Generalization	A discussion of the case studies of the potential use of SEASAT ocean condition data in the improved routing of dry cargo ships and tankers. Resulting forecasts could be useful in routing ships around storms, thereby reducing adverse weather damage, time loss, related operations costs, and occasional catastrophic losses.
VIII	Ocean Fishing - Case Study and Generalization	The potential application of SEASAT data with regard to ocean fisheries is discussed in this case study. Tracking fish populations, indirect assistance in forecasting expected populations and assistance to fishing fleets in avoiding costs incurred due to adverse weather through improved ocean conditions forecasts were investigated.
IX	Ports and Harbors - Case Study and Generalization	The case study and generalization quantify benefits made possible through improved weather forecasting resulting from the integration of SEASAT data into local weather forecasts. The major source of avoidable economic losses from inadequate weather forecasting data was shown to be dependent on local precipitation forecasting.
X	A Program for the Evaluation of Operational SEASAT System Costs	A discussion of the SATIL 2 Program which was developed to assist in the evaluation of the costs of operational SEASAT system alternatives. SATIL 2 enables the assessment of the effects of operational requirements, reliability, and time-phased costs of alternative approaches.

use of SEASAT-produced data in the areas of Arctic operations, marine transportation, and offshore oil and natural gas exploration and development.

During Fiscal Year 1976, the effort was directed toward the confirmation of the benefit estimates in the three previously identified major areas of use of SEASAT data, as well as the estimation of benefits in additional application areas. The confirmation of the benefit estimates in the three major areas of application was accomplished by increasing both the extent of user involvement and the depth of each of the studies. Upon completion of this process of estimation, we have concluded that substantial, firm benefits from the use of operational SEASAT data, can be obtained in areas that are extensions of current operations such as marine transportation and offshore oil and natural gas exploration and development. Very large potential benefits from the use of SEASAT data are possible in an area of operations that is now in the planning or conceptual stage, namely, the transportation of oil, natural gas and other resources by surface ship in the Arctic regions. In this case, the benefits are dependent upon the rate of development of the resources that are believed to be in the Arctic regions, and also dependent upon the choice of surface transportation over pipelines as the means of moving these resources to the lower latitudes. Our studies have also identified that large potential benefits may be possible from the use of SEASAT data in support of ocean fishing operations. However, in this case, the size

of the sustainable yield of the ocean remains an unanswered question; thus, a conservative viewpoint concerning the size of the benefit should be adopted until the process of biological replenishment is more completely understood.

With the completion of this second year of the SEASAT Economic Assessment we conclude that the cumulative gross benefits that may be obtained through the use of data from an operational SEASAT system to provide improved ocean condition and weather forecasts is in the range of $859 million to $2,709 million ($1975 at a 10 percent discount rate) from civilian activities. These are benefits that are attributable exclusively to the use of SEASAT data products and do not include potential benefits from other possible sources of weather and ocean condition forecasting that may occur in the same period of time. The economic benefits to U.S. military activities from an operational SEASAT system are not included in these estimates; however, a one-time military benefit of approximately $31 million attributable to SEASAT-A is included. A separate study of U.S. Navy applications has been conducted under the sponsorship of the Navy Environmental Remote Sensing Coordinating and Advisory Committee. The purpose of this Navy study was to determine the stringency of satellite oceanographic measurements necessary to achieve improvements in military mission effectiveness in areas where

benefits are known to exist.* It is currently planned that the Navy will use SEASAT-A data to quantify benefits in military applications areas. A one-time military benefit of approximately $31 million will be obtained by SEASAT-A, by providing a measurement capability in support of the Department of Defense Mapping, Charting and Geodesy Program.

Preliminary estimates have been made of the costs of an operational SEASAT program that would be capable of producing the data needed to obtain these benefits. The hypothetical operational program used to model the costs of an operational SEASAT system includes SEASAT-A, followed by a number of developmental and operational demonstration flights, with full operational capability commencing in 1985. The cost of the operational SEASAT system through the year 2000 is estimated to be about $753 million ($1975 at a 0 percent discount rate) which is the equivalent of $272 million ($1975 at a 10 percent discount rate). It should be noted that this cost does not include the costs of the program's unique ground data handling equipment needed to process, disseminate or utilize the information produced from SEASAT data. Figures 1.1 and 1.2 illustrate the net cumulative SEASAT exclusive benefit stream (benefits less costs) as a function of the discount rate.

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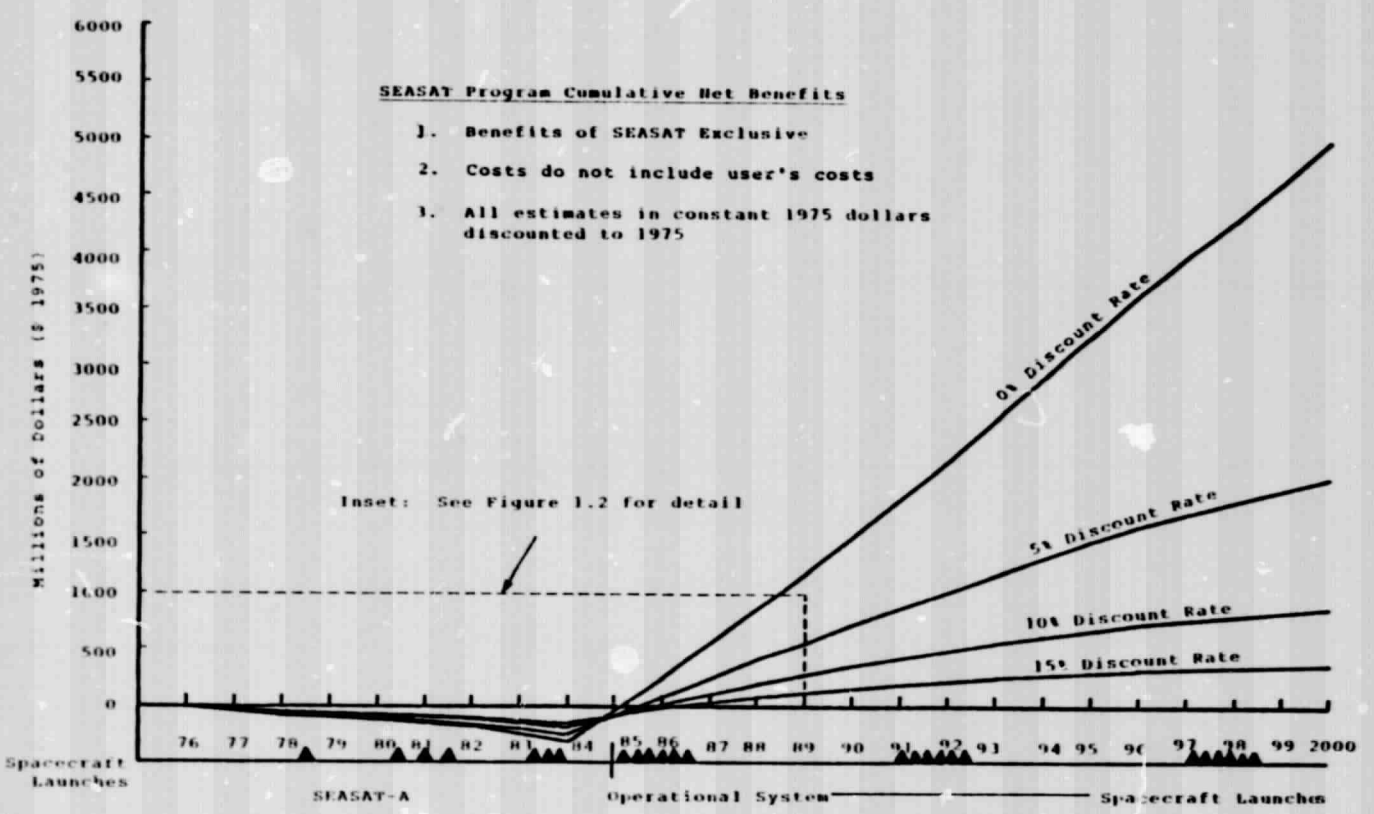
*"Specifications of Stringency of Satellite Oceanographic Measurements for Improvement of Navy Mission Effectiveness," (Draft Report). Navy Remote Sensing Coordinating and Advisory Committee, May 1975.



Costs*	19	49	78	100	121	151	184	239	307	152	368	373	375	393	437	503	546	566	568	587	625	695	738	753
Benefits*										311	622	933	1244	1555	1937	2319	2701	3083	3465	3847	4229	4611	5375	5757

*Cumulative Costs and Benefits at 0% Discount Rate (millions, $ 1975)

Figure 1.1 SEASAT Program Net Benefits, 1976-2000

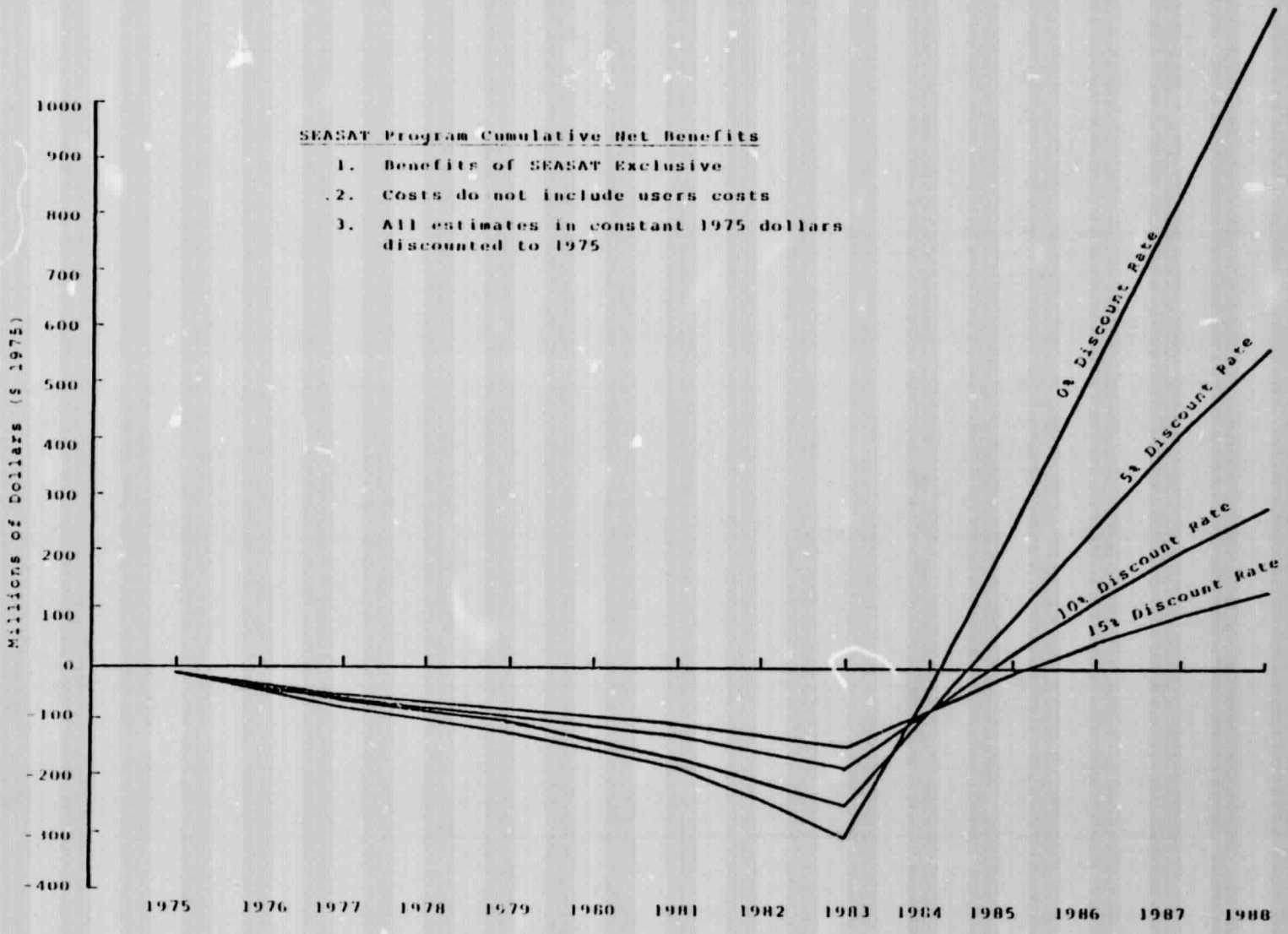


Figure 1.2 SEASAT Program Net Benefits, Inset

2. ORGANIZATION OF THE STUDY TEAM

The SEASAT Economic Assessment study team was organized at the start of the Fiscal Year 1975 effort as an informal economic working group consisting of representatives of industry and the U.S. Government. During Fiscal Year 1976, representatives of the Canadian Government (Canada Centre for Remote Sensing) also participated in the economic working group and made major contributions to the economic assessment. The organization of the economic assessment is shown in Figure 2.1. ECON, Inc., was responsible for the overall planning and management of the economic assessment and for the assignment of the individual study tasks performed by the members of the working group. Individual case studies were performed by each of the organizations shown. Interaction with the potential users of SEASAT data was obtained through the SEASAT Users Working Group (Ocean Dynamics Subcommittee) and through direct contact with industrial and governmental users in many of the case studies. The generalization of the results of the case studies and the integration of these results into this final report was performed by ECON, Inc. Table 2.1 shows the assignment of case studies for both the Fiscal Year 1975 and 1976 phases of the assessment.

In addition to the estimation of economic benefits through the process of case studies and their generalizations, as shown in Figure 2.1, two important related studies were begun

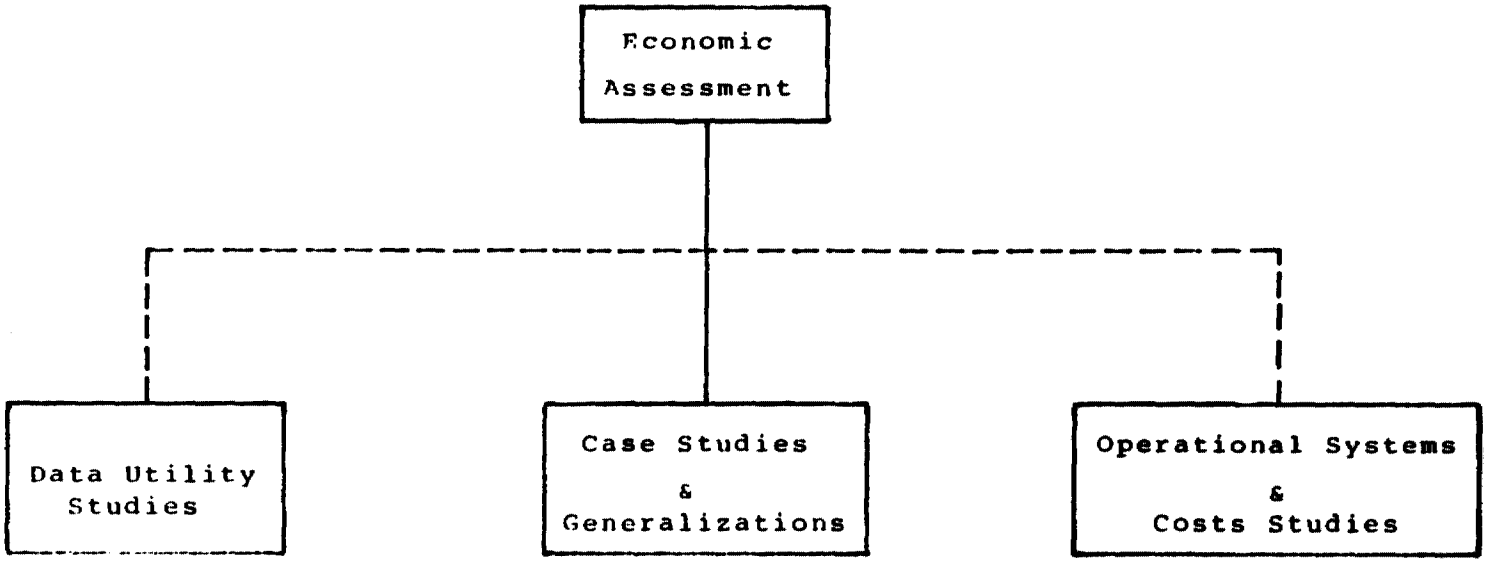


Figure 2.1 Framework of Assessment

Table 2.1 Assignment of Case Studies

Case Study	FY 1975	FY 1976
1. Arctic Operations	-----	Battelle, Canada Centre for Remote Sensing
2. Civil Applications of an Improved Geoid	Battelle	----------
3. Coastal Zones	-------	Battelle, Ocean Data Systems
4. Iceberg Reconnaissance	Battelle	
5. Ocean Fishing	-------	Jet Propulsion Laboratory
6. Ocean Mining	-------	Jet Propulsion Laboratory
7. Offshore Oil and Natural Gas	Battelle	Battelle, Canada Centre for Remote Sensing
8. Marine Transportation	Jet Propulsion Laboratory	ECON
9. Ports and Harbors	Jet Propulsion Laboratory	ECON
10. Sea Leg of the Trans-Alaska Pipeline	Ocean Data Systems	----------

during Fiscal Year 1976. The data utility studies performed by a team consisting of the Jet Propulsion Laboratory and the Goddard Institute of Space Studies, with the active participation and guidance of many other organizations interested in the potential use of SEASAT data, had as their objective providing empirical and experimental support to the quantification of the weather and ocean condition forecasting improvements that might be obtained by the use of SEASAT data. During Fiscal Year 1976, a program of experimentation was defined, and initial experiments with numerical forecasting models were performed at the Goddard Institute of Space Studies. The second related study, performed by the Jet Propulsion Laboratory with the support of ECON, Inc., dealt with the analysis of operational system requirements and the costs of these operational systems. In this area, during Fiscal Year 1975, efforts were directed toward the collection of a data base of expected user requirements. These data were used to estimate the technical capabilities and costs needed to meet these requirements and obtain the benefits estimated in the case studies and generalizations. The progress achieved in both of these related studies is described in the appropriate volumes of this report.

3. METHODOLOGY

The economic benefits of an operational SEASAT system were estimated by the use of interrelated micro and macroeconomic studies. The studies were performed on a by-industry or by-sector basis. The micro studies consisted of case studies, each case study being an in-depth examination of the potential benefits that might be obtained by the use of SEASAT data in a specific application. The results were then generalized on a by-industry or by-sector basis using appropriate econometric or economic models. Figure 3.1 is an overview of the methodology used in the economic assessment. The case studies, or application areas to be studied, were selected after a survey of the potential uses and users of the SEASAT data. The survey was performed by the SEASAT economic working group and was accomplished by the review of pertinent literature and by interviewing personnel from the prospective user organizations. The survey led to the identification of the prospective users of both the SEASAT data and the resulting improved weather and ocean condition forecasts. Users were identified within governments, institutions, and industries. In each case, an effort was made to understand how the user would apply the SEASAT data (or the improved weather and ocean condition forecasts) and what the expected areas of economic benefit would be from the application of these data. Although it was recognized at the outset that improved weather and ocean condition forecasts could affect both land-based and

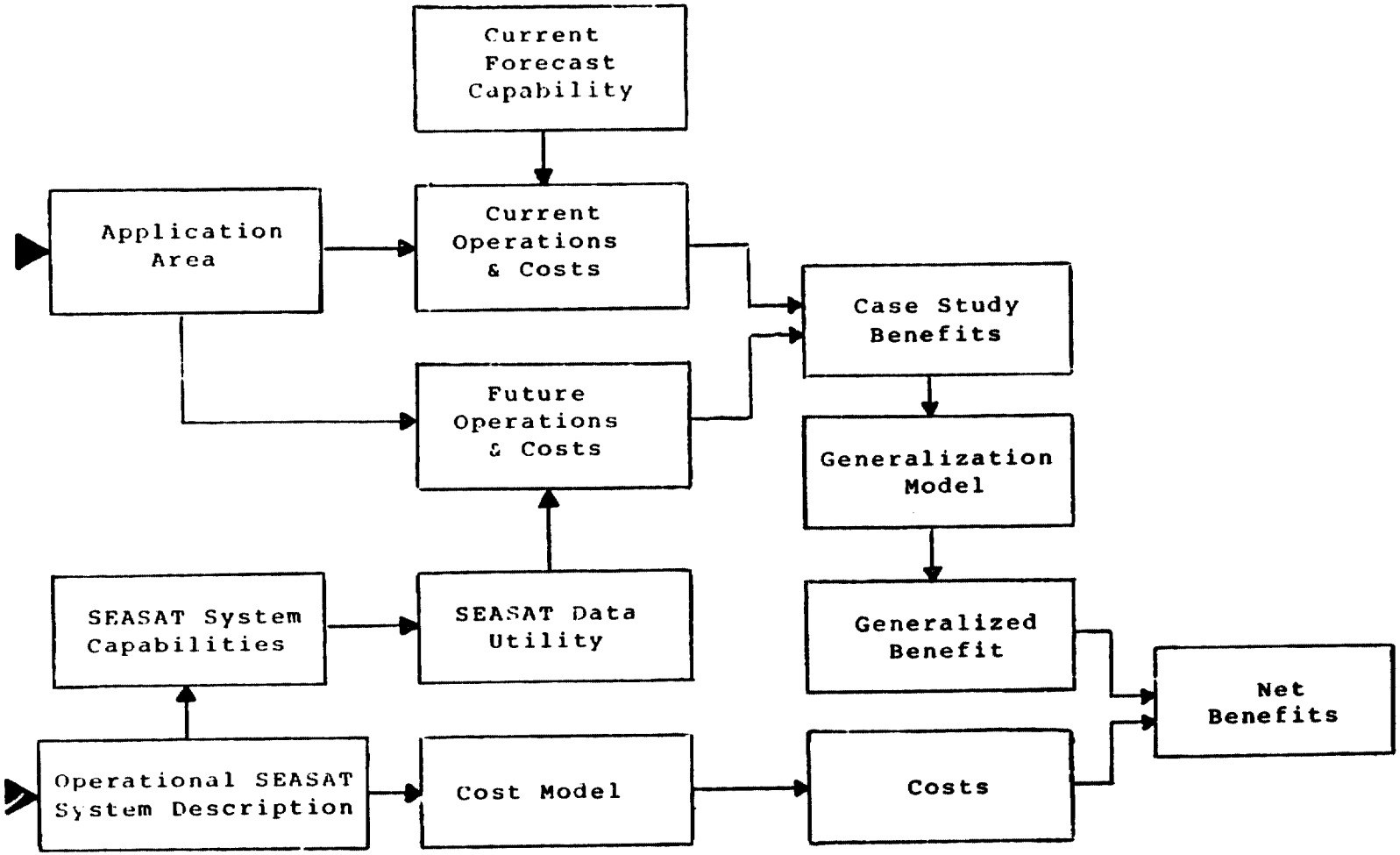


Figure 3.1 Study Methodology

ocean-based operations, it was decided to restrict the attention of this study to only ocean-based operations. The results of the survey led to the identification of specific industries or sectors whose economies could be affected by improved weather and ocean condition forecasts. Within these industries or sectors, specific applications or case studies were selected in consultation with NASA management and the SEASAT Users Working Group (Ocean Dynamics Subcommittee).

Each case study then became an in-depth examination of the operating parameters, constraints and structure of a selected maritime operation. As shown in Figure 3.1, the parameters of the selected application areas were then evaluated using current knowledge and predictive capability for weather and ocean conditions, and again using the expected improved capability for measurement and prediction of ocean conditions and weather as indicated by the SEASAT data utility. The incremental parameter changes attributable to the use of SEASAT data, or to the improved weather and ocean conditions derived from SEASAT data, were then estimated for each case study. These operating parameter increments then became the basis of the estimates of benefits to the operation under consideration.

The process of generalization was based upon the fact that each selected case study was one of a set of operations with generally similar technical and operational characteristics. With this condition, a generalization can be performed using appropriate econometric models and economic projections to bound and control generalizations.

Generalization of the case studies necessitated a careful formulation of each case study structure and its parameters that transform SEASAT derived information into economic benefits. Generalization also required that the class of operations represented by the case study be examined for each member of the class to determine the relationship between information and economic benefits. The process of generalization also required the extension of the results of the case studies to the dimension of scale (i.e., the relationship of samples to a population), time (the establishment of a valid planning horizon and forecasting quality variation), and geographical location (for example, extension of results obtained in the North Sea to other geographical sites for offshore oil exploration and development). This required the construction of appropriate physical models of weather effects and econometric models, and the collection and processing of data for use in these models. The planning horizon for these generalizations extended to the year 2000.

It is recognized that SEASAT data will be among the many important contributors to the improvement of ocean and weather condition forecasts in the period of 1985 to 2000. Thus, in each of the major expected benefit areas, two levels of benefits were estimated. An upper level of benefits was established on the basis of all expected improvements in ocean and weather condition forecasts, and the SEASAT specific benefits were then determined by estimating the level of improvement believed to

be attributable exclusively to SEASAT data. In many of the areas examined, an additional element of uncertainty was introduced by the uncertainty in the rate of development of the industry or sector under consideration. In these cases, upper, lower and most likely ranges of benefits were estimated.

4. SIGNIFICANT RESULTS

The cumulative gross benefits attributable exclusively to the use of SEASAT data and to the improved ocean and weather condition forecasts derived from the SEASAT data are considered to be in the range of $859 to $2709 million ($1975 at 10 percent discount rate). This is the combined benefit total of the 1975 revised case studies plus the standing 1974 case studies* (Figure 4.1). This is considered to be the most likely range of the SEASAT exclusive benefits in civilian applications. Figure 4.2 disaggregates the 1975 revised benefits by industry or sector. As may be seen, the main contributors are offshore oil and natural gas exploration and development, Arctic operations, marine transportation and ocean fishing. These four areas account for more than 90 percent of the estimated benefits. The results of the benefit studies in each of these four areas are discussed in the following paragraphs.

4.1 Offshore Oil and Natural Gas Exploration and Development

The use of improved weather and ocean condition forecasts by the offshore oil and natural gas industry accounts for approximately 13-25% of the total most likely SEASAT exclusive benefits. These benefits were derived from case studies in which operational data was obtained for production platform

*ECON, Inc., SEASAT Economic Assessment, October 1974, see Tables 1.2, 1.3 and 10.1.

	Integrated Benefits
	• Planning Horizon to Year 2000 • 1975 $ • 10% Discount Rate
1975 Revised Case Studies	
Offshore Oil & Natural Gas	214 - 344
Ocean Mining	not estimated
Coastal Zones	3 - 81
Arctic Operations	96 - 288
Marine Transportation	215 - 525
Ocean Fishing	274 -1432
Ports and Harbors	.5
1974 Standing Case Studies	
Alaska Pipeline	14
Unclassified Military	31
Iceberg Reconnaissance	12 - 39
TOTAL	859 - 2709

Figure 4.1 Summary of Total SEASAT Exclusive Benefits

- PLANNING HORIZON TO YEAR 2000
- 10% DISCOUNT RATE

INDUSTRY OR SECTOR	INTEGRATED BENEFIT ($1975 millions)
OFFSHORE OIL & NATURAL GAS	214 - 344
OCEAN MINING	NOT ESTIMATED
COASTAL ZONES	3 - 81
ARCTIC OPERATIONS	96 - 288
MARINE TRANSPORTATION	215 - 525
OCEAN FISHING	274 - 1432
PORTS AND HARBORS	0.5
TOTAL	802 - 2670

Figure 4.2 Summary of Most Likely Range of Benefits Exclusive to SEASAT for Revised 1975 Case Studies

installations in the North Sea in 1971, pipelaying and trenching in the North Sea and Gulf of Mexico in 1971 and 1972, and exploratory drilling by a drillship in the Celtic Sea during 1970. The generalization was performed by estimating the size of the offshore exploratory drilling rig population and the amount of pipe to be laid and trenched in the development of the offshore fields in the time period extending from 1985 to 2000. Geographically varying weather and ocean conditions were accounted for by the expected geographical distribution of the offshore exploration and development activities. The results of both the case study and its generalization were substantiated by an independent study of Canadian Arctic oil and gas exploration and development by the Canada Centre for Remote Sensing. Table 4.1 summarizes the generalization results for the offshore oil and gas industry as a function of discount rate. The most likely range of the cumulative SEASAT exclusive benefits is $214 to $344 million ($1975 at a 10% discount rate). Those benefits identified as attributable to "All Sources" and "All Sources Most Likely" represent the estimated range of benefits to the offshore oil and gas industry as a result of improved weather and ocean condition forecasts from all potential sources (including SEASAT) in the time frame under consideration.

4.2 Arctic Operations

The use of ice coverage information and improved ocean and weather condition forecasts in the transportation of resources from both the eastern and western Arctic regions accounts for

Table 4.1 Generalization Results for Offshore Oil and Gas Industry

DISCOUNT RATE%	0	5	10	15
	INTEGRATED BENEFIT 1985-2000 ($1975 MILLIONS)			
SEASAT EXCLUSIVE	464-2656	195-1113	87-501	43-244
SEASAT EXCLUSIVE MOST LIKELY	1136-1824	476-765	214-344	104-168
ALL SOURCES	1547-8853	650-3710	290-1670	143-813
ALL SOURCES MOST LIKELY	3787-6080	1587-2550	713-1147	347-560

approximately 11% of the total most likely SEASAT exclusive benefits. The case study considered the development of Arctic oil and gas resources and the transportation of these resources from the Arctic regions to the U.S. and Canada by a fleet of icebreaking tankers. As opposed to the offshore oil and gas industry case study that represents an existing industry, this case study was concerned with resource development that may take place in the future and also with an icebreaking tanker fleet that is yet to be designed and built. The results of this case study, performed jointly by the Canada Centre for Remote Sensing and the Battelle Memorial Institute, are summarized in Table 4.2. The case study indicates an annual benefit attributable to SEASAT data applications of $64 million to $234 million. The cumulative benefits, shown in Table 4.3 as a function of discount rate, are in the range of $96 million to $288 million ($1975 at a 10% discount rate).

4.3 Ocean Fishing

The use of SEASAT data by the ocean fishing industry accounts for 32% to 53% of the most likely cumulative SEASAT benefits. In this application, the case study was based upon the use of improved weather and ocean condition forecasts to improve the safety of ocean fishing operations, as well as the use of SEASAT-provided data on ocean currents and temperatures to improve the forecasting of the fisheries population. It was further assumed that international cooperation would be achieved in the management of ocean fisheries to obtain the maximum sustainable yield. The conditions needed to achieve the maximum

Table 4.2 North American Arctic Transit Case Study Results

CASE STUDY RESULTS

- WESTERN ARCTIC 1992-2000
  - + TRANSPORT 1.5 - 6.3 BILLION BARRELS OF OIL
  - + NUMBER OF VOYAGES 7900
  - + QUANTITY OF OIL PER TANKER 1.6 MILLION BARRELS
  - + ANNUAL BENEFIT $26 MILLION TO $494 MILLION *
- EASTERN ARCTIC 1990-2000
  - + TRANSPORT OIL, LNG, HYDROCARBONS
  - + PRODUCTION CONSISTENT WITH ALBERTA COMMISSION FINDINGS
  - + NUMBER OF VOYAGES ABOUT 13000
  - + AVERAGE ANNUAL BENEFIT $152 MILLION *
  - + BEAUFORT SEA BENEFIT $70 MILLION ANNUALLY BECAUSE OF ECOLOGY *

*Annual benefit ($1975) from all sources of improved weather and ocean condition forecasts and ice reconnaissance.

Table 4.3 Generalization of Arctic Operations Results

DISCOUNT RATE %	0	5	10	15
REGION	INTEGRATED BENEFITS TO SEASAT $1975 MILLIONS			
WESTERN ARCTIC	88 - 1600	29 - 551	11 - 203	4 - 79
EASTERN ARCTIC	547	219	85	35
NORTH AMERICAN ARCTIC	635 - 2147	248 - 770	96 - 288	39 - 114

sustainable yield are not yet understood and the needed international cooperation has not yet been obtained. The benefits in this application are considered to be somewhat speculative. If these conditions can be fulfilled, the possibility of a 1% to 4% improvement in the maximum sustainable yield was indicated by the case study results. Based upon these results, the cumulative benefit to the U.S. was estimated to be in the range of $30 million to $157 million ($1975 at a 10% discount rate). Considering the fact that the U.S. fishing catch (1974) is less than 5% of the world total estimated to be $274 million to $1432 million ($1975 at 10% discount rate), the potential worldwide benefits in this area are believed to be very substantial if the above stated conditions can be met.

4.4 Marine Transportation

The benefits to all segments of the marine transportation industry from the use of improved weather and ocean condition forecasts account for approximately 20% to 25% of the most likely cumulative SEASAT exclusive benefits. Three separate studies were conducted in the marine transportation industry. The first dealt with the benefits to the operation of the tanker fleet now under construction to transport oil from Valdez, Alaska, to the U.S. West Coast. The second considered container ship crossings on the North Atlantic between the U.S. and the United Kingdom on Trade Route Number 5. The third study considered worldwide tanker operations. In each of the studies two conditions were considered; the first was the reduction in transit time

(and its associated cost saving) that could be achieved by the use of improved weather and ocean condition information in optimum track ship routing; the second, the attendant reduction in damage or casualty losses associated with the reduced exposure to severe weather and ocean conditions. The generalization of the container ship case study employed an econometric model to forecast the demand for shipping on all U.S. trade routes to the year 2000. With consideration for the differences between trade routes, the benefits to shipping on all U.S. trade routes were estimated to be in the range of $27 million to $49 million per year ($1975).

The tanker study was performed by constructing profiles of each major world tanker route with respect to weather and weather-dependent sailing alternatives. A comparison of routed and unrouted tankers from the ship data files of Ocean Routes, Inc., for each of these major routes led to an estimate of time saving by route due to ship routing. Qualitative estimates of the potential incremental improvement possible with SEASAT data in this system were made using the route profiles and the routed/unrouted ship analysis. An analysis of tanker damage and losses by major route, according to standard publications, was performed to yield estimates of benefits from loss avoidance and damage avoidance. Finally, forecasts of tanker traffic on the major routes were made, and the results were generalized. Table 4.4 summarizes the results of the marine transport case studies and generalization. Approximately $19 to $94 million of the benefit

of $52 to $204 million to worldwide tanker operations' cumulative discounted (10% discount rate) benefit, (1985-2000) is attributable to time savings and $33 to $110 million to prevention of catastrophic losses. The final figure does not include consideration of costs of cargo loss, environmental damage and clean-up, loss of life, or vessel losses that are less than total losses.

Table 4.4 Marine Transportation Summary

Operation	Cumulative Benefit ($1975 at 10% discount rate)
U.S. Trade Routes - Dry Cargo	$113 million
Canadian - Trade Routes	$50-$208 million
Worldwide Tanker Operations	$52-$204 million
TOTAL	$215-$525 million